A TIME BASE CIRCUIT FOR A HIGH PRECISION IONOSPHERIC SOUNDING APPARATUS

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Plates XVI A and B.

ABSTRACT. The paper describes a high precision timebase circuit designed specifically for an ionospheric sounding apparatus This time-base circuit produces a ten-line raster time-base on the face of the oscilloscope tube Each line of the raster takes 333 micro-seconds which corresponds to 50 kms of ionospheric height This gives a reading accuracy of about 1/4 km. The time base also provides for 15 kc/s positive and negative marker pips which mark off 5 km intervals It also provides for an intensifying pulse on the grid of the cathode ray tube over the 333 microseconds interval corresponding to any one of the ten lines selected out by an ingenious line-selector arrangement

INTRODUCTION

The usual method of investigating the ionosphere consists of sending a series of short pulses from a pulse transmitter, receiving the "reflected" echoes from the ionospheric layers in a receiver, and displaying them on an oscilloscope. The time base of the oscilloscope produces a sweep of the cathode ray beam from left to right. The transmitted pulse and the ionosphere-echo produce momentary vertical displacements of the oscilloscope spot as the output of the receiver is connected to the vertical deflecting plates of the oscilloscope. The sweep length between the transmitted pulse and the ionosphere echo represents the delay between the transmitted and the reflected pulse which again represents the height of the ionised layers. This delay or equivalent height may be calculated from the sweep length between the pulses and the sweep velocity of the time base The sweep circuit is highly important in as much as the accuracy of these height measurements depends wholly on it. This paper describes a time base which gives an accuracy much higher than hitherto obtainable

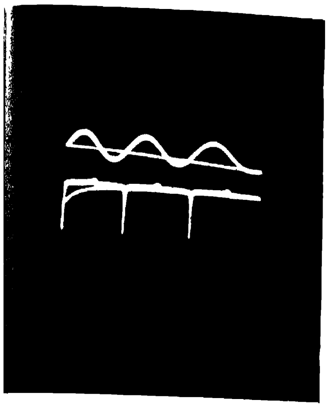
REQUIREMENTS OF A HIGH PRECISION IONOSPHERE SOUNDING TIME BASE

The ionised regions from which reflections are obtained extend upto a height of 400 kilometers and the sounding apparatus should be designed such that it is capable of measuring a maximum height of 500 kilometers. A height of 500 kms corresponds to a total time delay of 3.33 milliseconds. A single-line time base cannot usually measure times with an accuracy better than half per cent of 3.33 milliseconds, *i. e.*, 16 microseconds. This time corresponds to a height of 2.5 kms.

Increased accuracy may be obtained by a raster time base—one that gives a succession of lines up and down over the tube face. The cathode ray beam in such a time base will move from left to right at a high speed, and after it goes to the extreme right hand position, jumps back to the left within a short time and again moves from left to right. At the same time, as it moves from left to right, it also moves upwards at a slower rate so that when it jumps back after the completion of the first line, the spot does not come over the first position, but is shifted slightly upwards. The second line is therefore separated from the first, and the third line from the second and so on. If there are n lines in the raster, we get the length of the sweep virtually increased n times, which means that the resolution is increased n times.

The object of this paper is to describe a time base, designed specifically to suit the requirements of ionospheric sounding. It produces a raster of ten lines, each of 333 microseconds duration. Each line therefore corresponds to a height of 50 kilometers. Thus a total height of 500 kilometers is scanned. After scanning 500 kilometers, the light spot moves out and remains steady outside the pattern until the repetition period is over. The repetition frequency chosen for the present is 150 c.p.s., so the repetition time is 6.66 milliseconds The second reflection from the F_2 layer will come at a time delay between 3 3 and 6.6 milliseconds and will therefore appear at the steady position of the spot. It may be inspected at that position, if necessary The third and fourth reflection will come with a delay between 6.6 and 9.9 milliseconds and may cause confusion, superposing itself on the next raster. But it is presumed that its amplitude will by that time become sufficiently small to make it indistinguishable. If necessary, the repetition frequency may be reduced to 100 c.p.s. or 50 c. p. s. when the confusion with the higher order reflections will be avoided altogether. The high repetition frequency is chosen chiefly to compensate for the loss of brilliance of the oscillograph trace due to the fast sweeps.

The ten line raster, on a double beam tube occupies practically the whole space on the face of the tube. The spacing between the lines is therefore quite small As a result, if the pulse echoes are big enough, they may cut through the lines making it difficult to recognize as to which line they actually belong. To obviate this difficulty, a device has been provided by which any one of the desired lines may be selected and intensified. In this condition of operation, other lines are blanked out and the desired line is intensified by a positive pulse on the grid of the oscilloscope tube over the 333 microseconds interval covered by that line.



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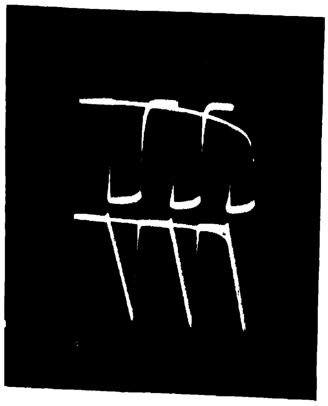

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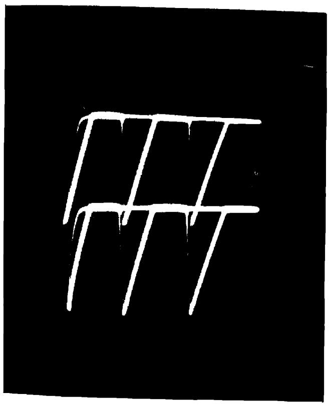

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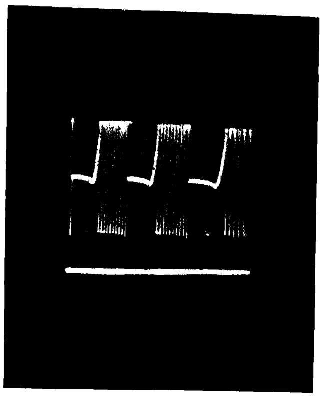


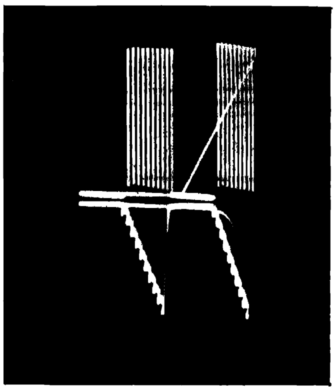
(d)

(a) Top—150 c p s. sine wave. Bottom—Positive spikes generated from it

(b) Top—Output of the cathode-coupled multivibrator Bottom—Sweep waveform from the boot-strap vertical time base

(c) Saw tooth waveform obtained with the aid of vertical deflection coils

(d) Shock-excited 3000 c p s. sinusoidal oscillations.



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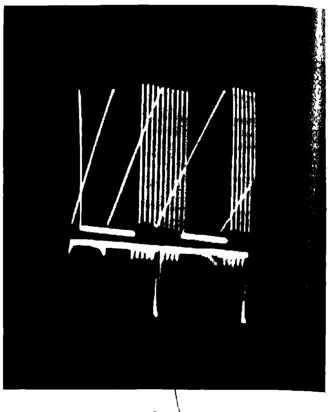

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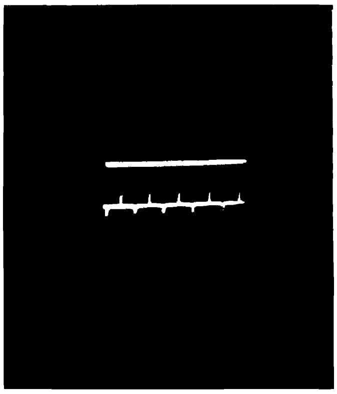

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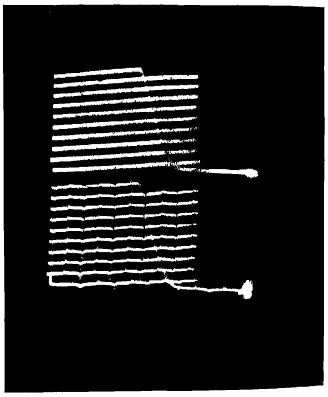


(h)

(e) Time base sweeps. Top Horizontal Bottom—Vertical

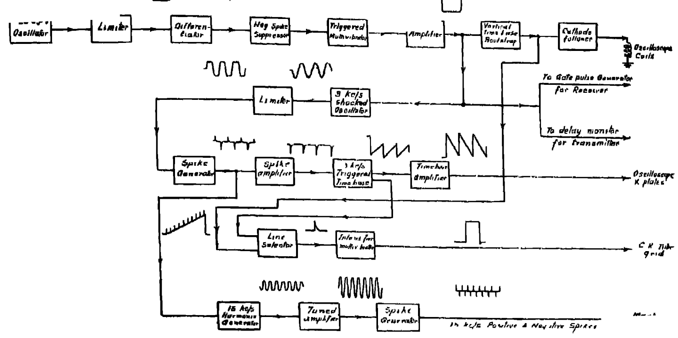
(f) Action of line selector and intensifier. Top—Sawtooth wave-form of the horizontal time base Bottom—Line selector selects and intensifier gives the positive pulse at the fifth line of the horizontal time base

(g) Single line selected and intensified Markers on one beam of the C R tube.

(h) 10 line raster time base with markers on one beam of the C R. tube

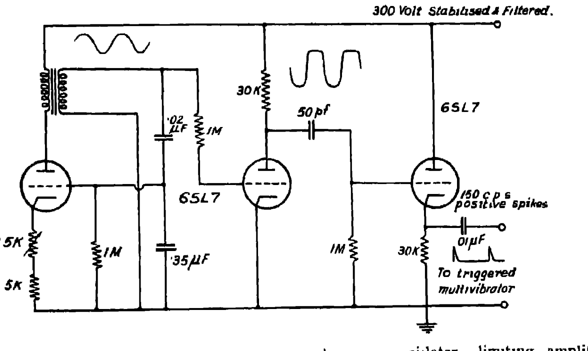
DETAILS OF THE CIRCUIT

The scheme for the time base may be understood from the block diagram given in Fig. 1 It starts with a sine wave oscillator (Fig. 2)



Block diagram of timer

FIG. 1

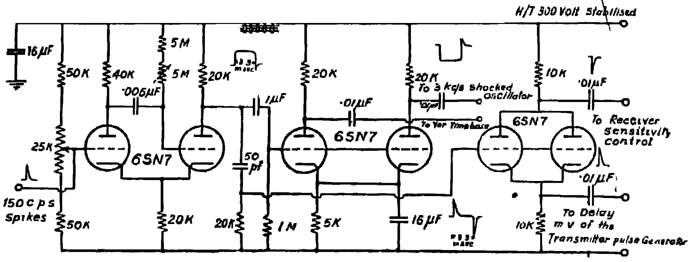


Repetition frequency generator 150 c.p s sine-wave oscillator, limiting amplifier, spike generator, negative-spike-suppressor.

FIG. 2

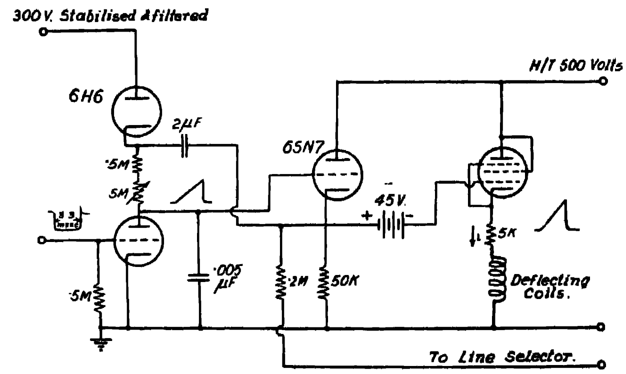
which generates a very pure sine wave at 150 c. p. s It applies a 200 volt, 150 c. p. s. A. C. to the high μ triode (6SL7) limiter grid through one-megohm series resistance. The limiter clips off this sine wave and produces an almost rectangular wave at its anode, about 200 volts peak amplitude. This is applied to the 50 pf., 1 meghom differentiating or spike generator circuit. The spikes are applied to a high μ triode (6SL7) cathode follower. This allows only the positive spikes to pass through. The negative spikes cannot produce a voltage change greater than four or five volts

The positive spikes of about 50 microseconds duration and 40 50 volts amplitude are applied to the trigger grid of a one-kick cathode-coupled multivibrator (Fig. 3) which generates a 100 volt positive rectangular output pulse of 3.3 milliseconds duration. A 6SN7 amplifier inverts this wave into a negative rectangular pulse of 180, 200 volts peak amplitude and 3 3 milliseconds duration. This cuts off the current in the 6SN7 time base generator (Fig 4). The current coming from the 300 volt stabilised supply, through the one megohm charging resistance charges the .005 mfd. time base condenser. The condenser voltage goes on increasing linearly with time. The cathode voltage of cathode follower 6SN7 also goes on increasing with time. This voltage is reapplied to the other end of the one megohm charging resistance through the 2 mfd coupling condenser. The 6H6 diode



Triggered multivibrator and amplifier.

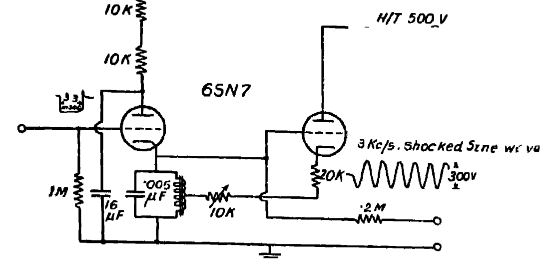
FIG. 3



150 c. p. s. boot-strap vertical deflection time base

FIG. 4

presents a very high impedance as its cathode voltage increases above the H. T. supply voltage, due to the application of the cathode follower output



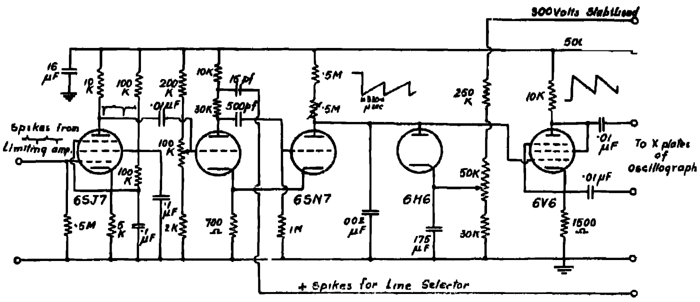
3 kc/s shocked oscillator

FIG. 5

to its cathode during the charging stroke. As a result of this connection, in spite of the increase in voltage of the time base condenser, the voltage across the one-megohm charging resistance remains practically undiminished, and so also the charging current. Thus we get an almost linear rise of voltage with time. The cathode follower 6V6 tube delivers the current necessary for the vertical deflection coil. The vertical sweep of 3.3 milliseconds is therefore established.

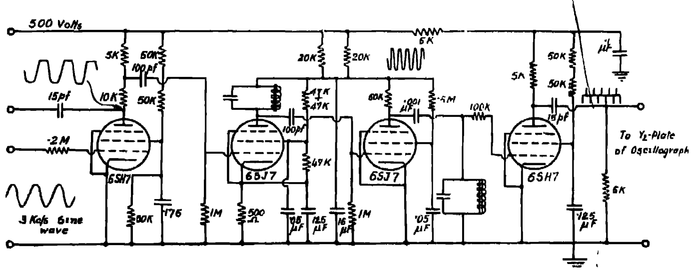
The 180-volt, 3.3 milliseconds negative rectangular pulse from the amplifier also excites the 3000 c. p. s. shocked oscillator (Fig. 5). The abrupt stopping of current in the 6SN7 excites an oscillation of 150 volts peak amplitude in the cathode *LC* circuit. This 3000 c. p. s. oscillation is the frequency or time standard of the whole time base. The small natural damping ($Q = 70$) of this circuit is compensated exactly by the right hand section of the 6SN7 giving positive feed back controlled by the 10 kilo-ohm potentiometer. The natural damping of this shocked oscillation is exactly compensated by adjustment of this potentiometer, while viewing the shocked oscillation on the oscilloscope. Ten complete periods of 3000 c. p. s. oscillation take place in 3.33 milliseconds.

The 150-volt peak 3000 c. p. s. oscillation is again applied through a 0.2 megohm series resistance to the 6SH7 limiter grid (Fig. 7). At its anode we get a 3000 c. p. s. rectangular wave of about 150 volts amplitude. The spike generator circuit applies positive and negative spikes of 40-50 volts to the grid of the 6SJ7 spike amplifier (Fig. 6), normally biased to cut off. The positive spikes get through this amplifier as negative pulses of 50-80 volts amplitude and 7 microseconds duration. This gets on to the grid of the 3000 c. p. s. horizontal time base.



Spike amplifier horizontal time base

FIG. 6



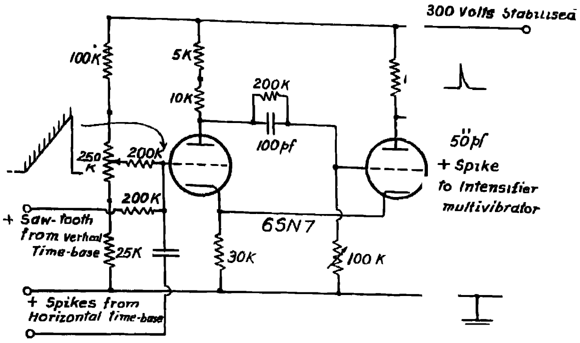
3000 c p s limiting amplifier 15 kc/s harmonic generator, limiter and 15 kc/s marker generator

FIG. 7

The first negative pulse discharges the 002 mfd. time base condenser from the voltage set by the clamping diode to a small value. When the discharge is complete, the condenser charges through the one-megohm charging resistance—from the 500 volts positive line. The condenser voltage rises exponentially until the second negative pulse again discharges it. The ten pulses produce the ten discharges and following the discharge ten charging strokes. The exponential rise is amplified by the 6V6 amplifier The natural curvature of the 6V6 characteristic compensates for the exponential curvature so that we get practically a linear sweep. After the tenth pulse and tenth discharge the condenser voltage rises and is clamped by conduction in the 6H6 diode, to its cathode voltage set to between 50-100 volts

The positive and negative spikes from the 3000 c. p. s. spike generator excite the 15 kc/s harmonic generator tuned by a 15 kc/s LC circuit whose Q value is 30 (Fig 7). This is further amplified by the 15 kc/s tuned amplifier feeding about 60 volts to the 15 kc/s limiter through a 100, 000 ohm series resistance. The 15 kc/s rectangular wave at the anode of the

6SH7 limiter are differentiated generating, 15 kc/s positive and negative spikes of 20 volts amplitude used as time markers.

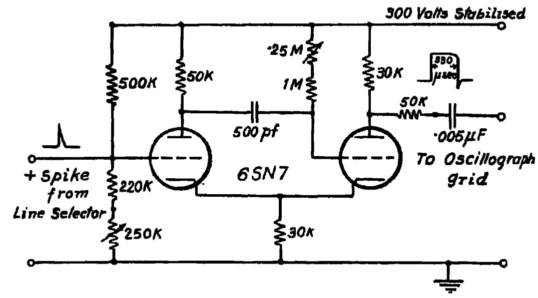


Line selector

FIG. 8

The difficult task of selecting out the desired line for intensification is allotted to the line selector (Fig 8). It is a Schmidt type trigger circuit which triggers at about 95 volts. To the input grid of this trigger circuit is applied—(*a*) the 3 3 millisecond saw-tooth from the vertical time base ; (*b*) a small adjustible fraction of the positive pulse obtained at the discharge of the 3000 c. p. s. horizontal time base ; (*c*) a d c. bias obtained from the line selector potentiometer When this d c bias voltage is greater than 95 volts, the trigger circuit remains triggered all the time—right from the beginning of the time base stroke As the d. c bias voltage is lowered, the circuit triggers at the start of the sweep—the first line when this bias voltage is just a little lower than 95 volts If the d. c. bias is reduced further, the circuit triggers later—when the voltage obtained from the 3.3 millisecond saw tooth makes the sum of the d. c. bias and saw-tooth voltage approach 95 volts. Thus it triggers at the second line, third line and so forth as the d. c. bias is progessively reduced. The tenth line is obtained close to the zero setting of the d c. potentiometer. The positive pulses that are obtained at the discharge of the horizontal time base strongly favour triggering at this time. This takes place just before the starting of each horizontal stroke. By a suitable adjustment of the amplitude of this positive pulse, triggering may be made to take place only at the start of the horizontal strokes and never in the middle or any other position.

When the trigger circuit switches over, the voltage at the output electrode jumps to the H. T. line voltage from a lower value. This jump of voltage—about 40 volts, impresses a positive spike to the input grid of the intensifier multivibrator (Fig. 9), which delivers a 90-volts positive intensifying rectangular wave to the cathode ray tube grid. The duration



Intensifier multivibrator

FIG. 9

of this positive unblanking rectangular pulse may be adjusted to 333 microseconds by the 1/4 megohm variable grid resistance.

CONCLUDING REMARKS

The merits and drawbacks of the time base described in this paper may be judged best if this time base is compared with typical and representative timing circuits that have been developed for radar ranging in the last war. This arrangement allows for a precision which outmatches all radars excepting those meant for precision long-range gunfire control. The possible reading error in this arrangement is of the order of one in two thousand at maximum range. This compares favourably with the best of gunfire control radars—such as the SCR-584. The weak spot of the circuit described in this paper is the determination of the timing by an *LC* circuit in comparison with the highly stable crystal control timing of the SCR-584. The crystal control timing of the SCR-584 gives better accuracy in absolute measurements. As regards comparision of ranges, this circuit is as good as the SCR-584 circuit. When measurements are made in terms of potentiometer settings of delay multivibrators, the accuracy obtained cannot be superior to that obtained in the circuit described in this paper.

It is not convenient or even practical to copy the SCR-584 scheme in developing a time base for a high precision ionosphere sounding apparatus. Besides requiring two type J oscilloscopes, it will need a greater number of frequency dividing multivibrators to obtain the very low repetition frequencies needed for the ionosphere apparatus. The arrangement we have made satisfies the requirements of ionosphere sounding more easily than a copy of any of the timing system developed for radar work.

This paper is the first publication of the research activities in a scheme for developing improved ionospheric sounding apparatus entitled "A New Technique of Investigating the Ionosphere".

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